USING PHET SIMULATIONS TO IMPROVE STUDENTS' REPRESENTATION ABILITY ON THE TOPIC OF CHEMICAL REACTIONS

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ABSTRACT

This research aims to determine whether there is an increase in students' representation abilities after using PhET Simulations on the topic of chemical reactions. This type of research was quasi-experimental using a pretest and posttest control group design. This research involved two groups of students, namely the experimental group using PhET Simulations during the learning process while the control group only used conventional worksheets. The data collection technique used a 25-item test that refers to indicators of representational ability. This hypothesis test uses the t-test (Independent Sample t-Test) using the assumption that the data is normally distributed and homogeneous. The results of the analysis show that there was an influence of using PhET Simulation in improving students' representation abilities at MA Al-Hikmah as evidenced by the sig (2-tailed) value of 0.000 < 0,05 so that H_0 is rejected with the n-Gain value in the experimental class of 0.71 which is in the high category.

Keywords: *Representation abilities, PhET simulations, Chemical reactions.*

1. INTRODUCTION

Chemistry is an abstract subject when viewed from the various concepts contained in the chemical material itself. The many changes in material at the atomic and molecular level and the use of symbols and formulas make this subject difficult for students to understand. According to Chittleborough and Treagust (2007), chemistry includes macroscopic, submicroscopic, and symbolic levels that are interconnected with each other. Representation at the macroscopic level is a level of chemical representation obtained through observation of phenomena that can be seen and felt by students' senses or phenomena that occur in real everyday life. Chemical phenomena can be observed at the macroscopic level, but their explanations often lie at the sub-microscopic level (Petillion & McNeil, 2020; Rahmawati et al., 2022). In addition, many phenomena at the sub-microscopic level are represented symbolically such as the use of atomic symbols, compounds, and the use of chemical equation symbols.

Lessons in chemistry subjects can be understood thoroughly if the learning involves concepts at the macroscopic, submicroscopic, and symbolic levels (Correia et al., 2019). One of the chemistry lessons that must be built on understanding and describing concepts at three levels of representation is chemical reactions (Hinton & Nakhleh, 1999). At the macroscopic representation level, students are required to be able to observe phenomena that occur, either through experiments carried out or phenomena that occur in everyday life. Observed phenomena can include the appearance of odors, color changes, the formation of gases, and the formation of precipitates in a chemical reaction. Sub-microscopic representation provides an explanation at the particle level where matter is described as a composition of atoms, molecules, and ions while symbolic representation is used to represent macroscopic phenomena using chemical reaction equations.

According to Chandrasegaran et al. (2009), when studying the concepts contained in chemistry lessons, many students have difficulty understanding these concepts, this is caused by the students' inability to connect macroscopic and submicroscopic phenomena. Therefore, students cannot directly feel and see the submicroscopic level making it difficult to visualize a chemical reaction (Abdoolatiff & Narod, 2009; Salame & Makki, 2021).

The concept of chemical reactions is a basic concept that must be understood before understanding other chemistry lessons such as chemical calculations, acids and bases, equilibrium, reaction rates, and many more.

Even though it is one of the most important chemical concepts in chemistry, many students have difficulty understanding the concept of chemical reactions (Seliwati, 2023). Because molecules are invisible and concepts are abstract, it is difficult for beginners to represent and make connections involving sub-microscopic levels with macroscopic observables (Hinton & Nakhleh, 1999; Salame & Makki, 2021).

Representation ability is students' ability to describe scientific concepts, theories, and findings through various forms, images, and symbols (Ahmar et al., 2020; Sari & Seprianto, 2018). Russell and Kozma, (2005) explicitly state representation skills as a term used to describe several skills and practices that reflect the use of a diversity of representations. By using representation skills, students will better understand the abstract concepts in chemistry by combining the macroscopic level and sub-microscopic level into a symbolic level through chemical equations (Bucat & Mocerino, 2009; Rahmawati et al., 2022; Sari & Seprianto, 2018). On the other hand, most students have difficulty representing various chemistry concepts. This is under the results of observations at the MA Al-Hikmah school in Bandar Lampung where 97% of students felt confused and had difficulty when studying chemical material, especially material related to atoms, molecules, ions, and chemical reaction equations. Because most students have difficulty representing various chemical phenomena using reaction equation symbols, teachers should use interactive simulations to illustrate how reaction equation symbols describe a chemical phenomenon and its relationships at the sub-microscopic level.

Animation and simulation play an important role in visualizing the sub-microscopic level which plays an important role in the teaching and learning process of chemistry in the classroom (Liu et al., 2021; Moore et al., 2014). Interactive simulations make it easier for students to represent phenomena at the sub-microscopic level, make invisible things visible, play a role in the investigation process, and allow several experiments to be carried out with fast feedback while being interesting and fun for students and teachers (Correia et al., 2019; Nuraida et al., 2021; Pratiwi et al., 2023). In addition, interactive simulations are easily accessible online, allowing users to use them flexibly.

The Physics Education Technology (PhET) was used in this research to find out how much influence it has in improving students' representation abilities after visualizing equation symbols in chemical reactions and compound molecules. This simulation has been widely used in chemistry education because it provides many advantages, including being easily accessible and free. This interactive simulation can provide dynamic access to various levels of representation so that it will help students understand objects that cannot be observed directly by eye (Rahmawati et al., 2022; Salame & Makki, 2021; Watson et al., 2020). This is under the results of Correia et al. (2019) research which states that by using PhET simulations students can represent the behavior of gases at the sub-microscopic level using symbols in the form of images.

Based on the description above, this research aims to analyze students' representation abilities after using PhET Simulations in chemical reaction lessons.

2. METHODS

Population and Sample

This research was at the MA Al-Hikmah Bandar Lampung school with the population in this study being 70 class X students at MA Al-Hikmah Bandar Lampung. Sampling in this study was carried out using a purposive sampling technique considering that the abilities of the two classes were almost the same, so 37 students in class XA1 were obtained as the experimental class and 33 students in class XA2 as the control class**.**

Research Design

The research method used was quasi-experimental with a pretest-posttest control group design (Fraenkel et al., 2012) This research was carried out by providing a treatment in the form of using PhET simulations in the experimental class and the control class only using conventional worksheets. The worksheets used in the control class are worksheets containing lesson material and practice questions. This research design looks at the differences in students' pretest and posttest before and after treatment between the experimental class and the control class.

Table 1. Research Design

Class	Pretest	Treatment	Posttest
Experimental	O	X_1	O
Control	O	C	O

Keterangan:
O : Experimental class and control class pretest-posttest
X1 : Experimental class's treatment (using PhET Simulations)
C : Use of conventional worksheets

The research instruments used in this study were pretest and posttest questions as many as 20 multiple-choice questions and 5 description questions using indicators of representation ability (Russell & Kozma, 2005). Indicators of representation ability can be seen in Table 2.

Table 2. Indicators of Representational Ability

Representational abilities (Russell & Kozma, 2005)	**Indicator**
Using representations to describe chemical phenomena based on molecular entities and processes	Using various symbols in a chemical reaction based on the phenomenon that occurs.
Deriving/selecting a representation and providing an explanation of why the representation is suitable for a particular purpose	Determine representations in the form of images to explain molecular phenomena in a chemical reaction
Using words to identify and analyze patterns of certain representational features (such as the behavior of molecules in an animation)	Explain chemical phenomena based on existing reactions
Describe and explore how different representations express the same or different things	Explain different types of reactions using different representations
Connecting various representations by mapping the features of one type of representation into another type of representation and explaining their relationships	Using other representations to describe the same chemical reaction
Take an epistemological position of the representation that is appropriate or has a difference from the observed phenomenon	Determine the representation used based on existing chemical phenomena
Using representations and their features in social situations to make inferences and predictions about observed chemical phenomena.	Counting the number of compounds contained in a chemical reaction; balance the chemical reaction

Data on students' representation abilities was processed using Microsoft Office Excel 2019 software and analyzed using SPSS version 25.0 for Windows software. The steps for processing student pretest-posttest data are (1) calculating student answer scores; and (2) calculating the pretest and posttest scores using the following formula:

$$\text{Score } = \frac{\Sigma \text{ answer score}}{\text{maximum score}} x \ 100$$

calculate the n-Gain value for each student, using the following formula:

$$n - Gain = \frac{posttest\ scores - pretest\ score}{100 - pretest\ score}$$

calculate the average n-Gain value, the representational ability of each student's n-Gain value using the following formula

$$< n - Gain > = \frac{\sum n - Gain \text{ students}}{\text{Number of students}}$$

interpret the criteria for the average n-Gain value, as follows:

Table 3. n-Gain value criteria

n-Gain	**Criteria**
> 0,7	High
0,3 < n-Gain ≤ 0,7	Medium
n-Gain ≤ 0,3	Low

(Source: Hake, (2002))

After data processing, analysis of the n-Gain values obtained was carried out using SPSS version 25.0 to obtain normality, homogeneity, and differences in the two averages of student pretest-posttest data from the two samples. Data normality was tested using the Kolmogorov-Smirnov test with a significance level of > 0.05. Homogeneity of data by looking at the One Way ANOVA value with a significance level of > 0.05. The difference test between the two averages was carried out using an independent sample t-test from the average n-Gain value of the representation ability of students in the two samples with the results of the n-Gain average test, the representation ability of students who applied learning using PhET simulation had a significant difference compared to The average n-Gain representation ability of students who use conventional worksheets is if the sig (2-tailed) value is <0.05.

3. RESULTS & DISCUSSION

Based on the research that has been carried out, research results were obtained in the form of pretest-posttest score data on students' representational abilities. The test instrument in the form of pretest-posttest questions before being given to students has been measured for validity and reliability, and it is stated that the pretest-posttest questions are valid and reliable so that the test instrument is declared suitable for use to measure students' representational abilities. Data on the average pretest-posttest scores for both classes can be seen in Figure 1.

Based on Figure 1, it can be seen that there is a difference between the average pretest and posttest scores in the experimental class and the control class. It can be seen that there was an increase in the average score of students before (pretest) and after (posttest) the implementation of learning in both the experimental and control classes. The calculation results show that the average increase in the pretest-posttest score for the experimental class is higher, namely 66.9, compared to the control class, namely 42.35. This increase in representation ability is shown through the n-Gain value. The average n-Gain value in the experimental class and control class is shown in Table 4.

Table 4. Average n-Gain value in the control and experimental classes

Class	Average of n-Gain	category
Control	0.43	Medium
Experimental	0.71	High

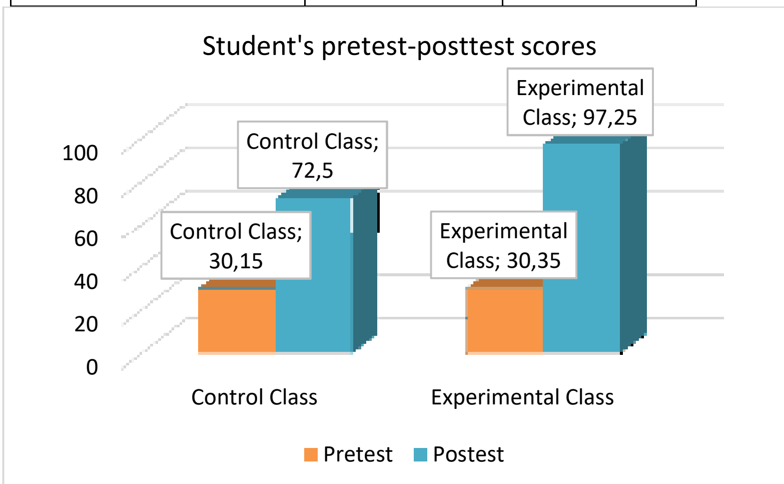


Figure 1. Student's Pretest-Posttest Score

Based on Table 4, it can be seen that there is a difference between the average n-Gain value of representational ability in the control class and the experimental class. This shows that the control class has "medium" n-Gain criteria and the experimental class has "high" n-Gain criteria. This shows that the use of PhET Simulations is effective in improving representation skills on the topic of chemical reactions. PhET Simulations can improve student learning outcomes in chemistry learning (Sa'diyah & Lutfi, 2023; Warsiki, 2023). With PhET simulations, students are helped to understand the number of atoms in a compound so that it is easier for students to balance existing chemical reactions. This has an impact on understanding the next concept, namely the concept of moles and chemical calculations. Students who already understand the concept of chemical reactions will find it easier to carry out chemical calculations.

Hypothesis Test

Hypothesis testing is a test of the difference between two means. This test uses the n-Gain value to find out whether there is a difference in the average n-Gain value in the representational abilities of experimental class and control class students. Before carrying out this test, a normality test and homogeneity test must be carried out. The results of the normality and homogeneity tests can be seen in Table 5.

Table 5. Results of the normality test of the n-Gain value of students' representational abilities

Class	N	*Sig. Test of Normality Kolmogrov-Smirnov*	Criteria
Control	33	0,200	*Sig > 0,05*
Experimental	37	0,200	

Based on Table 5, it can be seen that the average normality test results of the n-Gain value of the representational ability of students in the experimental class and control class show a sig value > 0.05 so that based on the test criteria, accept H_0 and reject H_1, which means the sample comes from a population with a distribution normal. Based on the test results, the homogeneity test was continued. The homogeneity test results can be seen in Table 6.

Table 6. Homogeneity test results of the n-Gain value of representation ability

Class	N	Homogeneity test	
		Sig. value	Criteria
Control	33	0,438	*sig.* > 0,05
Experimental	37		

Based on Table 6, it can be seen that the results of the homogeneity test for the two variants of the experimental class and the control class have an n-Gain value of 0.438, which means the sig value is > 0.05, so the test decision is to accept H_0 and reject H_1, which means both classes are the control class and the experimental class. has a homogeneous population variance. Based on this, the test was continued with the independent sample t-test. The results of the difference test between the two averages can be seen in Table 7.

Table 7. Results of the independent sample t-test of students' representation abilities

Class	N	t-test	
		Sig. *(2-tailed)*	Criteria
Control	33	0,000	*sig.* < 0,05
Experimental	37		

Based on Table 7, it can be seen that the results of the difference between two averages using the Independent Sample t-test on the average n-Gain representation ability of students in the experimental class and control class show a sig (2-tailed) value of 0.000 < 0.05 so that based on the test criteria, it is to accept H1 and reject H0, which means $\mu_{(1x,y)} < \mu_{(2x,y)}$ which means that the average n-Gain learning outcomes of students who use PhET simulation have a significant difference compared to the average n-Gain learning outcomes of students who use conventional student worksheets

This research shows that there is a significant positive influence of the use of PhET Simulations on students' representational abilities in chemical reaction material. The use of visualization using animation and simulation can help students understand difficult concepts related to the dynamics of complex chemical concepts by combining interactive multimedia (animation and simulation) using PhET simulation. Students are helped to understand concepts at the molecular level that students cannot observe directly.

In the experimental class, the macroscopic level is presented through images and then integrated with the submicroscopic level through PhET Simulations visualization. Then it is connected to the symbolic level, namely through chemical equations and formulas. The three levels of representation (macroscopic, sub-microscopic, and symbolic) in an integrated manner can help students understand chemical phenomena so that in the future they can be applied in problem-solving strategies (Farida, 2009).

During the learning process, initially, students found it difficult to create a chemical formula to represent a compound, but this could be overcome with the help of PhET simulation in the "Build a molecule" feature. It is easier for students to imagine water compounds consisting of two hydrogen atoms and one oxygen atom. PhET simulation has a role in helping students visualize their understanding of chemical concepts that exist at the molecular or sub-microscopic level (Correia et al., 2019; Nuraida et al., 2021; Pratiwi et al., 2023; Rahmawati et al., 2022). By understanding the concepts they have regarding compound molecules, students will find it easier to understand chemical reaction lessons.

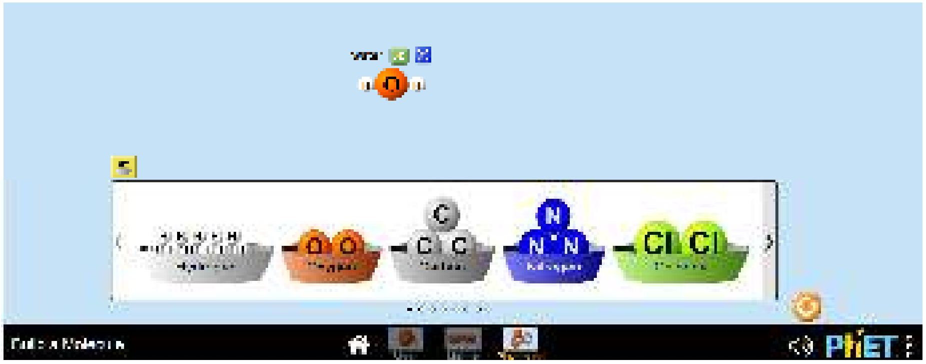
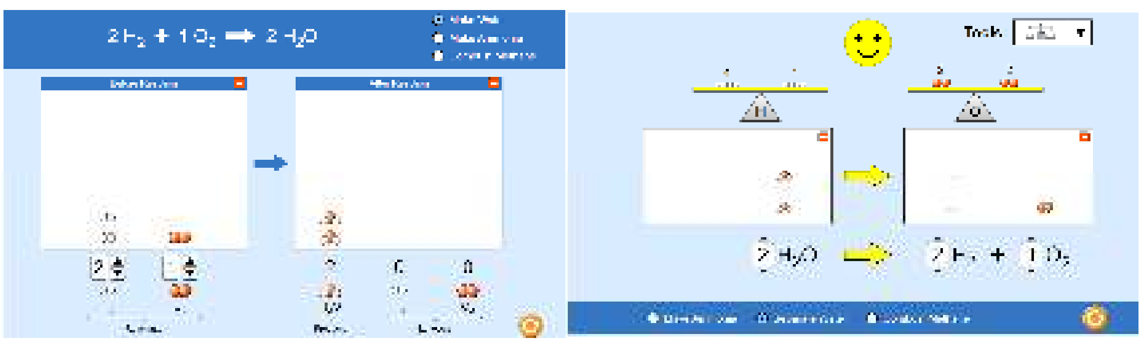


Figure 2. Build a Molecule feature in PhET Simulations

By using PhET Simulations, students can determine the components of reactants, products, and reaction residues where this concept will be very useful in chemical calculations. Students can also easily calculate the number of atoms in a reaction equation, which will later be used in the concept of balancing chemical reactions. From the interview results, 95% of students felt helped in imagining chemical reactions that occur in everyday life. Students can also easily balance the given reaction equations. PhET simulation only provides features for ammonia production, water decomposition, and methane gas combustion. However, during learning activities, students can create their representation in the form of a round image to represent the number of atoms in the reaction equation, so that students can balance chemical reactions because they understand the number of each atom on the left and right sides of the reaction equation. Apart from that, in PhET Simulation there are game features that can increase motivation and enthusiasm for learning (Sa'diyah & Lutfi, 2023). Following are several images from PhET Simulation which can be seen in Figure 3.



(a) (b)

Figure 3. Various features of PhET Simulations: (a) reactant, product, and reaction residue components; (b) balancing chemical reactions

4. CONCLUSION

Based on the results of data analysis and discussion, it can be concluded that the use of PhET Simulations is effective in improving representation abilities in chemical reaction material. This can be seen through the significant difference between the n-Gain values in the control and experimental classes, where the experimental class has a higher average n-Gain value than the experimental class. With PhET simulations, students are helped to understand the number of atoms in a compound so that it is easier for students to write reaction equations based on everyday chemical phenomena. This has an impact on understanding the next concept, namely the concept of moles and chemical calculations. Students who already understand the concept of chemical reactions will find it easier to carry out chemical calculations.

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